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(54) Cold-cathode tube lighting circuit with protection circuit for piezoelectric transformer

(57) To provide a cold-cathode tube lighting circuit which quickly and smoothly carries out lighting of a cold-cathode tube and prevents damage of a piezoelectric transformer as an inverter transformer in the lighting circuit, the lighting circuit is provided with a protection circuit for detecting a primary current of the piezoelectric transformer. The protection circuit stops operation of an oscillator for driving the piezoelectric transformer when the primary current is excessive. The protection circuit may be provided to detect excess of a secondary voltage of the piezoelectric transformer. When the cold-cathode tube is used as a backlight for a liquid crystal display driven by the use of a scanning frequency, a dimmer circuit is used for producing a dimmer signal with a dimmer frequency and a controlled duty ratio given by a manual selector for controlling start and stop of the oscillator according to a desired brightness of the backlight. The dimmer frequency is obtained from frequency division of the scanning frequency. The controlled duty ratio is also modified corresponding to the divided frequency.

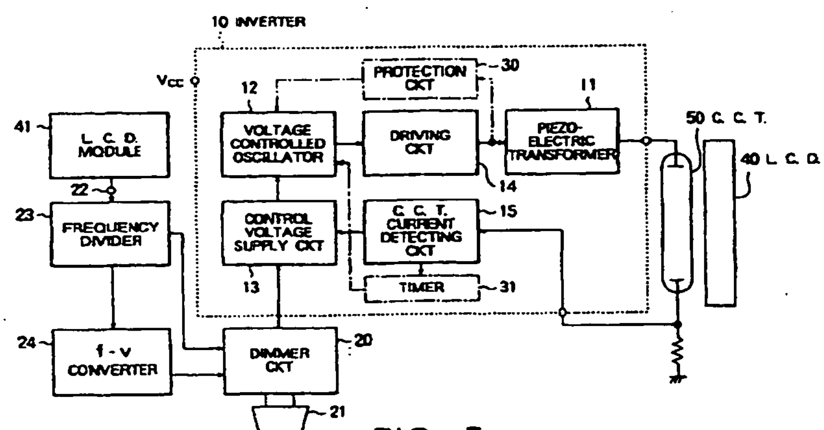

FIG. 5

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to produce a detection signal dependent on the current detected, the voltage controlled oscillator being controlled in the oscillating frequency by the detection signal; and a protection circuit for protecting the piezoelectric transformer in response to a load impedance of said piezoelectric transformer.

[0017] Preferably, the cold-cathode tube lighting circuit further comprises a dimmer circuit for producing a dimmer signal with a dimmer frequency and a controlled duty ratio corresponding to a desired brightness of the cold-cathode tube. The voltage controlled oscillator is controlled by the dimmer signal to intermittently operate every ON duration of the dimmer signal.

[0018] The cold-cathode tube may be a backlight for a liquid crystal display by scanning by a driving signal under a scanning frequency. Preferably, the cold-cathode tube lighting circuit further comprises a frequency divider to be connected to the liquid crystal display for frequency-dividing the scanning frequency to produce a divided signal with a divided frequency. The dimmer circuit is responsive to the divided signal and produces the dimmer signal having the divided frequency as the dimmer frequency.

[0019] Preferably, the cold-cathode tube lighting circuit further comprises a frequency voltage converter connected to the frequency divider and responsive to the divided signal for producing a voltage signal corresponding to the divided frequency. The dimmer circuit is responsive to the voltage signal and modifies the controlled duty ratio so as to maintain the desired brightness of the cold-cathode tube under a change of the scanning frequency.

Brief Description of The Drawings:

[0020]

Fig. 1 is a circuit diagram showing a cold-cathode tube lighting circuit comprising an inverter using a piezoelectric transformer known in the prior art;

Fig. 2 is a block diagram showing a cold-cathode tube lighting circuit comprising an inverter using a piezoelectric transformer known in the prior art;

Fig. 3 is a block diagram showing a cold-cathode tube lighting circuit having a protection circuit according to an embodiment of the present invention;

Fig. 4 is a block diagram showing a cold-cathode tube lighting circuit having another protection circuit according to another embodiment of the present invention; and

Fig. 5 is a block diagram showing a cold-cathode tube lighting circuit having a light control circuit according to another embodiment of the present invention.

Description of preferred Embodiments:

[0021] Prior to description of preferred embodiments, description will be made as regards two types of a conventional cold-cathode tube lighting circuit with reference to the drawing.

[0022] Referring to Fig. 1, an inverter 1 used in a conventional cold-cathode tube lighting circuit uses a piezoelectric transformer 11. When a DC voltage +Vc is applied to an input port of the inverter 1, a switching transistor or driving transistor 5 turns on so that an output voltage of the driving transistor 5 is applied to a primary side of the piezoelectric transformer 11 through input terminals 2 and 3. As a result, a primary current flows through a voltage divider resistor 6 for detecting an output.

[0023] A voltage across the voltage divider resistor 6 caused by the primary current is amplified by an amplifying transistor 7, and then controls switching of the driving transistor 5. In this manner, the switching frequent of the driving transistor 5 follows a resonance frequency of the piezoelectric transformer 11 to maintain the self-oscillation so that a cold-cathode tube 50 connected to an output terminal 4 of the piezoelectric transformer 11 can be lighted.

[0024] The cold-cathode tube lighting circuit has a problem at the start or-power-on condition as described in the preamble.

[0025] Referring to Fig. 2, there is shown another type of the known lighting circuit which is used for lighting a cold-cathode tube (C.C.T.) 50 as a backlight of a liquid crystal display 40. The lighting circuit has an inverter 10 which comprises a piezoelectric transformer 11, a voltage controlled oscillator (V.C.O.) 12, a control voltage supply circuit 13, a driving circuit 14, and a cold-cathode tube (C.C.T.) current detecting circuit 15. The lighting circuit further has a dimmer circuit 20 with a manual selector or adjuster 21 for producing a dimmer signal for burst controlling the luminescence of the cold-cathode tube 50 so as to control the brightness thereof.

[0026] After the power VCC is turned on, the voltage controlled oscillator 12 produces an oscillating signal with an oscillating frequency determined by a control voltage given from the control voltage supply circuit 13. The oscillating signal is supplied to the driving circuit 14 and switches a switching transistor therein to apply a switched power as a primary power to the primary side of the piezoelectric transformer 11. Therefore, the oscillating frequency is a switching frequency. A secondary output of the piezoelectric transformer 11 is applied to the cold-cathode tube 50 for lighting its Then, a low current flows through the cold-cathode tube 50. The current is detected as a detected voltage signal at the cold-cathode tube current detecting circuit 15. In detail, the cold-cathode tube currant detecting circuit 15 comprises a resistor connected to the cold-cathode tube 50, and a rectifying and smoothing circuit connected to the resistor An AC voltage is generated across the resistor

predetermined timer operating time of, for example, several seconds. The timer circuit 31 is released when the cold-cathode tube current is detected at the cold-cathode tube current detecting circuit 15 before the timer operating time is expired. On the other hand, unless the cold-cathode tube current is detected during the timer operation, the timer circuit 31 produces a timer signal when the timer operating time has expired. The timer signal is supplied as another stop signal to the voltage controlled oscillator 12. Thus, the voltage controlled oscillator 12 stops delivering its output to the driving circuit 14.

[0035] Referring to Fig. 4, the lighting circuit shown therein in in a modification of the circuit of Fig. 3. In detail, the protection circuit detects not the primary current of the piezoelectric transformer 11 but the secondary voltage of the piezoelectric transformer 11, as shown at 30'. When the protection circuit 30' detects an excess voltage over a predetermined voltage on the secondary side of the piezoelectric transformer 11 the protection circuit 30' produces the detection signal. The protection circuit 30' comprises a voltage comparator which has two inputs connected to a secondary output of the piezoelectric transformer 11 and a reference voltage source, respectively, and an output. When the secondary output voltage of the piezoelectric transformer 11 is excessive the reference voltage, the detection signal is produced on the output. The detection signal is supplied as the stop signal to the voltage controlled oscillator 12, and therefore, the voltage controlled oscillator 12 stops oscillation.

[0036] Referring to Fig. 5, the cold-cathode tube lighting circuit shown therein is similar to the lighting circuit of Fig. 2, but provision of control of the diner circuit 20. The similar portions are denoted by the same reference numerals and description thereof is omitted for the purpose of simplification.

[0037] The cold-cathode tube lighting circuit is provided with a connection terminal 22 to a liquid crystal panel module 41 of the liquid crystal display 40 and receives a driving signal of the liquid crystal display from the liquid crystal panel module 41 connected thereto. The cold-cathode Cube lighting circuit had a frequency divider circuit 23 which is applied with the driving signal of the liquid crystal display 40 from the module 41 and divides its scanning frequency to produce a signal having a divided frequency (the signal is hereinafter referred to as a "divided signal"). The dividing ratio can be properly determined depending on necessity. The divided signal is supplied to the dimmer circuit 20.

[0038] The dimmer circuit 20 carries out a waveform conversion (or waveform shaping) of the divided signal into a triangular wave signal of the see divided frequency and further carries out another waveform conversion from the triangular waveform signal into a square wave signal. Before the waveform conversion into the square wave signal, the reference level of the triangular wave is adjusted using a duty ratio set by the manual selector 21. Accordingly, the converted square wave signal has the duty ratio corresponding to a desired brightness. In this manner, the dimmer signal is supplied to the control voltage supply circuit 13 to control the brightness of the cold-cathode tube 50.

[0039] Since the frequency of the dimmer signal is synchronous with the driving scanning frequency of the liquid crystal display, the interference fringes are prevented from appearing on the display screen. Further, the frequency of the dimmer signal is synchronized with the scanning frequency of the liquid crystal display only by connecting the liquid crystal panel module 41 to the cold-cathode tube lighting circuit. Therefore, it is advantageous that no setting change or adjustment of the frequency of the dimmer signal is necessary even relative to a liquid crystal display having a different scanning frequency.

[0040] It will be noted that, when the dimmer frequency changes under a constant duty ratio, the sum of ON times for a unit time does not become constant. Accordingly, the time-averaged luminous intensity, that is, the brightness, of the cold-cathode tube 50 does not become constant. Therefore, there is an inconvenience that even if the manual selector 21 is adjusted to a same duty ratio according to the same brightness, the brightness of the cold-cathode tube 50 is not controlled to the same brightness in case of a liquid crystal display having a different scanning frequency.

[0041] For solving such inconvenience, the cold-cathode tube lighting circuit further includes a frequency-voltage conversion circuit (f-v converter) 24. The f-v converter 24 is applied with the divided signal from the frequency divider circuit 23 and converts it into a voltage signal corresponding to the frequency thereof. This voltage signal is supplied to the dimmer circuit 20.

[0042] In response to the voltage signal, the dimmer circuit 20 modifies the reference level selected by the manual selector 21 so that the duty ratio of the dimmer signal is modified in dependence on the dimmer frequency for the same desired brightness selected by the manual selector 21. Therefore, with no relation to the scanning frequency of the liquid crystal display 40, the actual brightness of the cold-cathode tube becomes constant for the same operation of the manual selector 21. The cold-cathode lighting circuit of Fig. 5 can also provide with the protection circuit 30 and the timer 31 described in connection with Fig. 3, as shown by imaginary lines and blocks with same reference numerals in Fig. 5. The protection circuit 30' shown in Fig. 4 can also be used in place of the protection circuit 30.

Claims

1. A cold-cathode tube lighting circuit for lighting a cold-cathode tube (50) which comprises:

   a piezoelectric transformer (11) having a given resonance frequency for producing an AC out-

prises a piezoelectric transformer (11) having a given resonance frequency for producing a lighting voltage for the cold-cathode tube (50), a voltage controlled oscillator (12) oscillating at a frequency near said resonance frequency, a driving circuit (14) for driving said piezoelectric transformer in response to an output of said voltage controlled oscillator (12), and a back light current detection circuit (15) for detecting a current flowing through said cold-cathode tube (50) connected to said piezoelectric transformer (11), said voltage controlled oscillator (12) being controlled in an oscillation frequency by a detection signal from said back light current detection circuit (15), and said voltage controlled oscillator (12) being also controlled to start and stop its operation by the dimmer signal from said dimmer circuit (20).

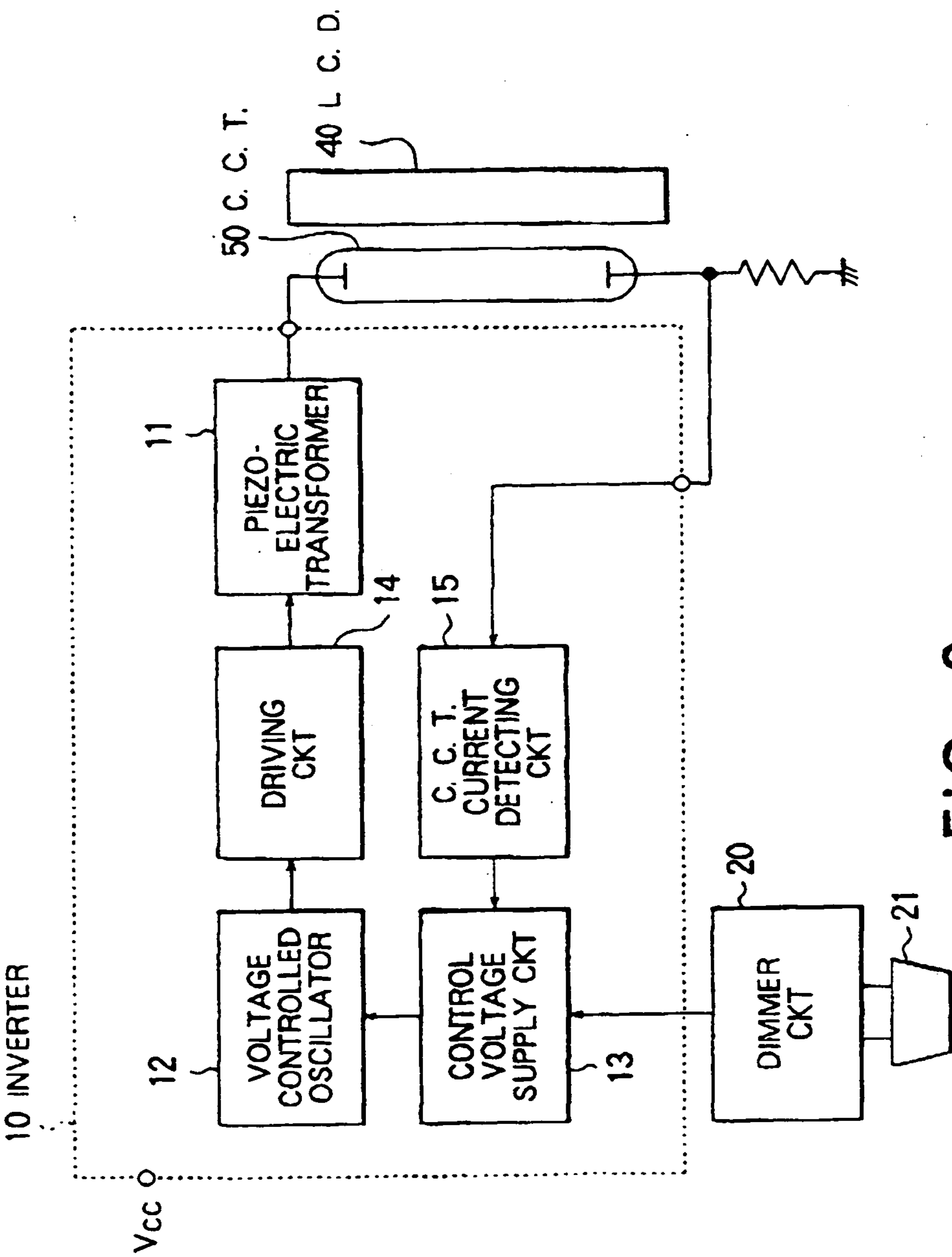

FIG. 2
PRIOR ART

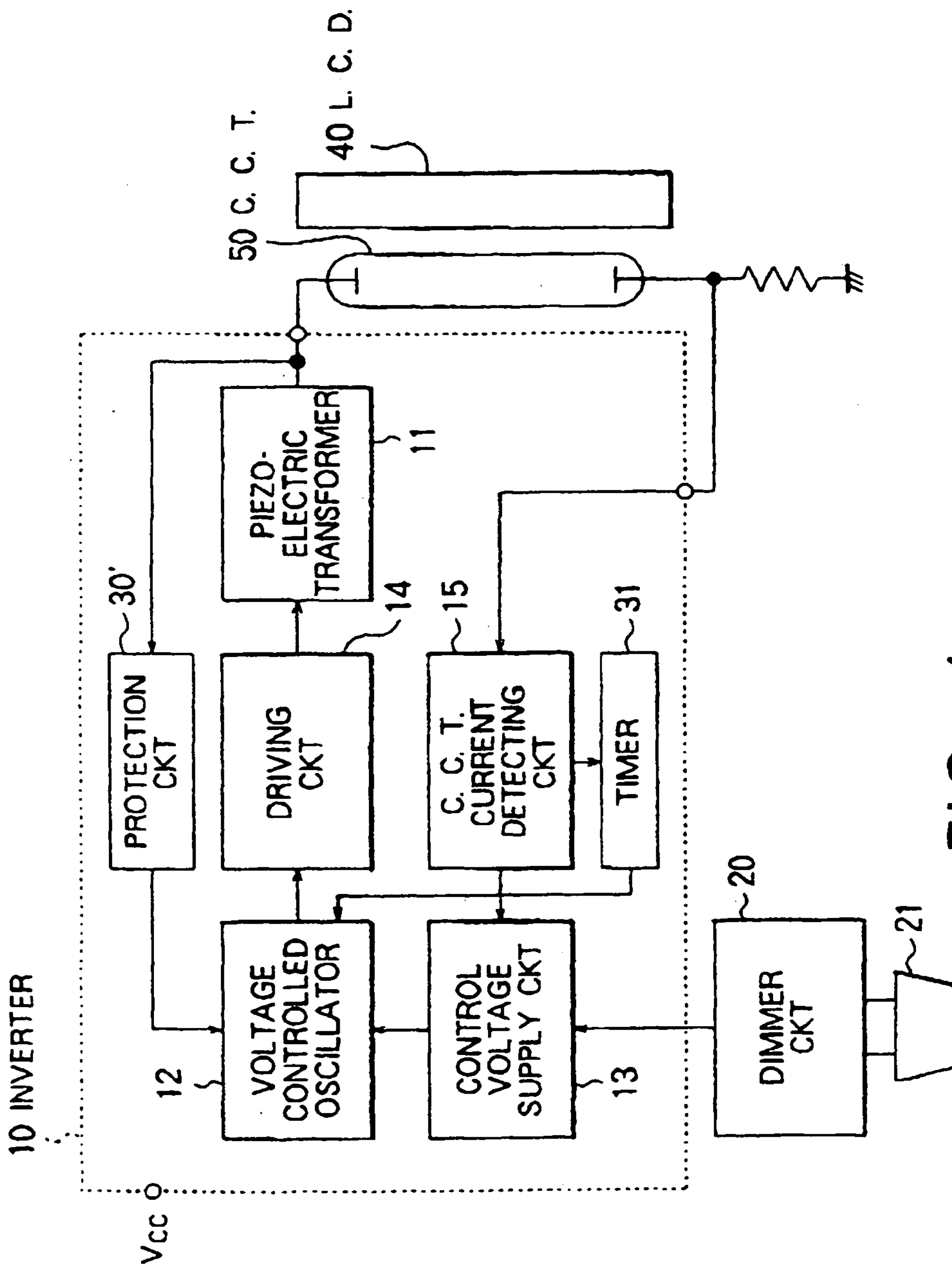
10 INVERTER
Vcc
PROTECTION CKT
30'
VOLTAGE CONTROLLED OSCILLATOR
12
DRIVING CKT
14
PIEZO-ELECTRIC TRANSFORMER
11
CONTROL VOLTAGE SUPPLY CKT
13
C. C. T. CURRENT DETECTING CKT
15
TIMER
31
DIMMER CKT
20
21
50 C. C. T.
40 L. C. D.

FIG. 4